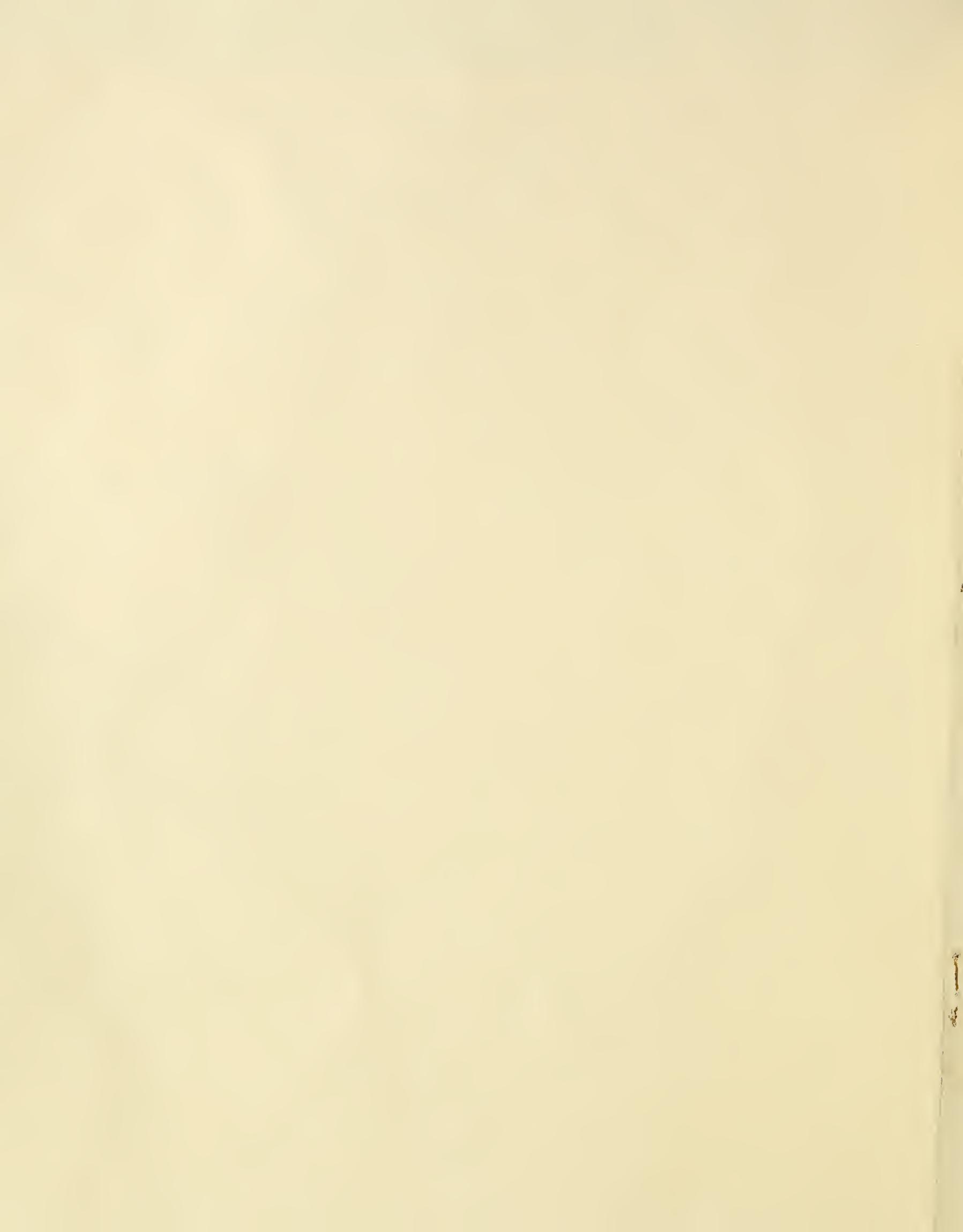


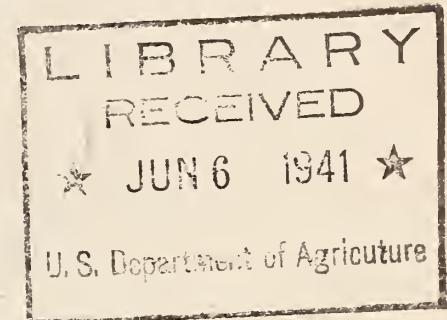
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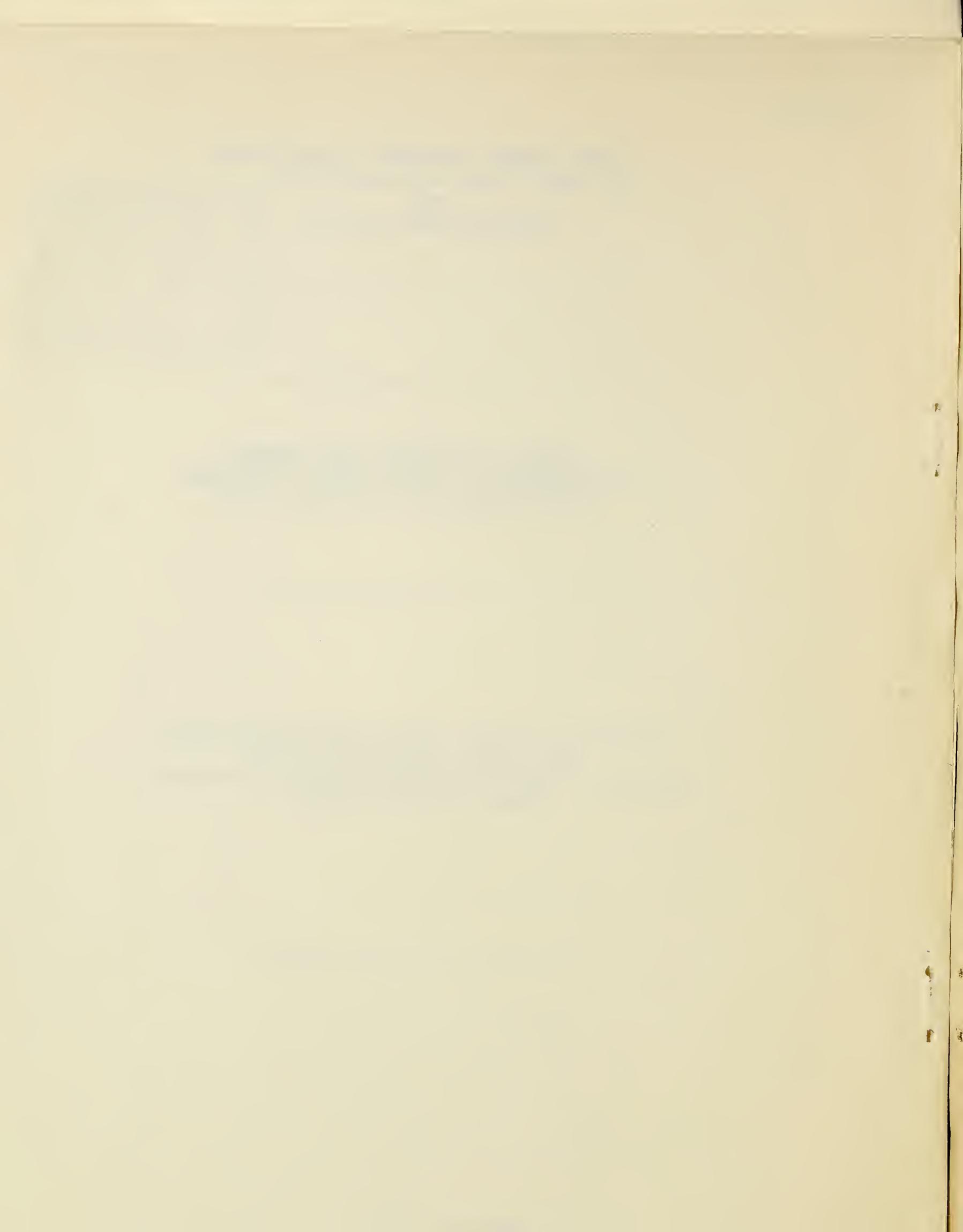
UNITED STATES DEPARTMENT OF AGRICULTURE
U.S. Agricultural Marketing Service
and
Bureau of Plant Industry



A METHOD OF MEASURING THE STRENGTH
OF ATTACHMENT OF COTTON FIBERS TO THE SEED
AND SOME RESULTS OF ITS APPLICATION

By William S. Smith, Junior Cotton Technologist,
Agricultural Marketing Service,
and Norma L. Pearson, Associate Cotton Technologist,
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INTRODUCTION

In connection with the experimental cotton ginning program of the United States Department of Agriculture 2/ it was desirable to ascertain: whether seed cottons (varieties) differ in their mean strength of fiber attachment to the seed and, if so, whether these differences are reflected in ginning efficiency and lint quality.

Fortunately, the force necessary to detach a cotton fiber from the seed is usually less than the force necessary to break it at some other point. If this were not the case, ginning with our present machinery would break the fibers into small pieces instead of detaching them as entire fibers. From this fact it can be reasoned that the more closely the force required to detach a fiber from the seed approaches the tensile strength of that fiber, the greater is the possibility that that fiber will be broken or damaged during ginning, and vice versa.

1/ The authors wish to express their indebtedness to Charles A. Bennett, Senior Mechanical Engineer, U. S. Cotton Ginning Laboratory, and his associates, for constructing the new single fiber testing instrument and for their helpful suggestions in regard to its design.

2/ These experiments are being conducted jointly by the Agricultural Marketing Service and the Bureau of Agricultural Chemistry and Engineering.

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The strength of attachment of the fibers to the seed may also affect the efficiency of the ginning process. It may require more time and therefore more energy to gin cottons whose fibers are strongly attached to the seed than cottons whose fibers are less strongly attached. The strength of fiber attachment may also affect the cleanliness with which the seeds are ginned (lint percentage or turn-out); the roughness of the lint, or preparation; and the amount of seed-coat fragments in the lint.

A survey of the literature relating to this subject revealed that very little work had been done upon these problems.

So far as available records show, strength of fiber attachment as related to ginning efficiency first attracted the attention of Forbes Watson ^{3/} one of the pioneers in cotton-ginning research. He considered strength of attachment of the fibers to seed and the "striking speed" at which separation of the fibers from the seeds is effected, as the two most important technical factors in cotton ginning. He found that certain cottons differed considerably in the energy consumed during ginning. The energy consumed in ginning a unit quantity of cotton was measured by deducting from the total energy consumed, the energy allowed for friction in the machinery, for turning the seed roll etc. He states (Vol. 2, p. 61): "The difference thus shown to exist between several varieties of cotton in respect to the power consumed in their cleaning ^{4/} can be accounted for in two ways: Differences in the strength of attachment of fibers to the seed, and the differences in roughness of the seed." Roughness applies to fuzziness: large fuzzy seeds remain in the seed roll longer than do slick seeds and they obstruct the action of the gin. Watson states further that not only do cottons whose fibers are attached tenaciously require more power for ginning than do cottons with fibers more weakly attached, but the fibers are more likely to be torn and cut and the seeds are more likely to be crushed and broken.

Dewey and Goodloe ^{5/} measured the force necessary to detach single fibers from the seed by means of an apparatus for testing the tensile strength of single fibers. They state (p. 19): "In American upland varieties this (strength of attachment) ranges from 1.88 to 2.30 grams and in Sea Island from 1.75 to 1.95 grams."

^{3/} Watson, Forbes. Report on Cotton Gins and on the Cleaning and Quality of Indian Cotton. Parts I and II. William H. Allen and Co., 13 Waterloo Place, London, 1879.

^{4/} In this paper the term cleaning is used synonymously with the term ginning.

^{5/} Dewey, Lyster H. and Goodloe, Marie. The Strength of Textile Plant Fibers. U. S. Dept. of Agr., Bur. Plant Industry Circ. 128: pp. 17-21, 1913.

Federow ^{6/} states: "Through research work on cotton fibers we have discovered that on the average the strength by which the fibers are held to the seed coat is about forty-five to fifty percent of the breaking strength of a single fiber. Of course, this strength is not constant, and it varies according to the type (nature) of the cotton, its maturity, and the place where it is grown. Thus, for American type cotton it averages about forty-five to sixty percent of the strength of the individual fiber. So, if the strength is four and a half grams, the force required to remove the fiber from the seed is from 2.0 to 2.7 grams." Unfortunately more detailed records of Federow's research have not become available.

Sorkin, Kuz'men, Topol'skain and Liporskii ^{7/} in studies relating to the effect of seed cotton moisture on the productivity of gins and on the quality of the fiber, give figures representing the "degree of fiber attachment" for cottons of different moisture content. These figures range from 1.51 grams to 2.11 grams. No mention is made, however, as to the method used for finding these figures.

In light of the foregoing it is evident that no information was available as to whether varieties of upland cottons differ in the amount of force required to detach their fibers, or whether, with modern ginning machinery the strength of fiber attachment is a factor affecting efficiency of ginning. Since cotton ginning is of great industrial importance, and is a necessary process in cotton marketing and utilization, any information leading to greater efficiency in ginning or preserving the quality of the cotton is especially desirable. Therefore, a program designed to obtain this information was outlined by this laboratory. Three steps were involved: (1) To develop a technique for measuring the strength of attachment of fibers to the seed; (2) to test different seed cottons (varieties) in order to ascertain whether differences in mean strength of fiber attachment exist; and (3) if such differences were found, to gin these same cottons and determine whether differences in strength of fiber attachment are correlated with the time and energy consumed in ginning and with lint quality.

The following progress report is concerned with the first two steps--the development of a technique and the testing of individual cottons.

RELATIONSHIP OF COTTON FIBERS TO THE SEED COAT

Before proceeding to the detailed consideration of the problems associated with the objectives, it would seem advisable first to consider, briefly and in a general way, the relationship of the cotton fiber to the seed coat and some of the morphological problems that may be concerned with the separation of fibers from the seed.

^{6/} Federow, W. S. Cotton Ginning Research. The Cotton and Cotton Oil News 34(20): 3-4, 1933.

^{7/} Sorkin, N. B., Kuz'men, V. T., Topol'skain, O.N., and Liporskii, J. E. The Effect of Seed Cotton Moisture on the Productivity of Gins and on the Quality of the Fiber. Trust of Cotton Cleaning Industry of the Uzbekeston, U.S.S.R. Collected Works No. 4. Experimental Ginnery, pp. 90-115, 1935. Translated by Rimsky Korsakoff.

A cotton fiber is the outward elongation of a single cell of the epidermis of the cotton seed. Thus the basal portion of the mature cotton fiber is below the surface of the seed coat, and serves to connect the fiber to the seed.

The basal portion of a very young fiber is not very different from the surrounding undifferentiated epidermal cells except that it is somewhat larger (fig. 1, A and B). At maturity, however, there are conspicuous differences between the basal portions of the fibers and the epidermal cells that surround them (fig. 1, C).

A surface view of a portion of a mature seed coat which has been delinted shows the epidermal cells to be very irregular in outline, to have very thick walls and dark contents (fig. 1, D). The places occupied by the basal portion of the fibers can be recognized as small, clear, irregularly shaped areas situated at the convergence of several epidermal cells. Longitudinal views of mature cotton fibers that have been dissected out from the epidermis (fig. 1, E, F, G, H, I) reveal that the basal portions have various irregular shapes, ranging from those that are cone-like and cylinder-like to those that resemble an hour glass. Usually, the extreme inner (basal) portion spreads out somewhat and sometimes even flares out considerably beyond the limits of the opening left by the surrounding epidermal cells (fig. 1, C). These irregular shapes are probably brought about by the lateral pressure exerted by the growing epidermal cells upon the bases of the cotton fibers.

In detaching fibers from the seed, the basal portion of some fibers is pulled from between the epidermal cells, other fibers are broken at or very near the outer surface of the epidermis, and still others are broken at some distance above the seed coat. Preliminary observations indicate that, when ginning is done by machinery, more fibers are broken off than when the fibers are pulled off individually by hand. Stumps of broken fibers, however, do not form a large percentage of the fibrous material left on machine ginned seeds. The majority of this material is made up of the fuzz fibers, which are too short to be ginned, and by some longer lint fibers that have escaped ginning.

The place where the rupture will occur when a single fiber is detached is determined by various factors. It is possible that the size and shape of the basal portion of the fiber, or the presence of abnormalities near its point of attachment to the seed, and other morphological characteristics may exert some influence on where the fiber will become detached and may therefore affect the amount of force required to detach it.

DEVELOPMENT OF A TECHNIQUE FOR SAMPLING AND FOR MEASURING THE FORCE REQUIRED TO DETACH FIBERS FROM THE SEED

In the absence of adequate apparatus the first step was to find, adapt, or construct an instrument for measuring, both rapidly and accurately, the force required to detach fibers from the seed.

Probably any apparatus for testing the tensile strengths of single fibers could have been adapted to the work, but the operation of these instruments is very tedious and time consuming. Therefore an effort was made to find some method that would be more satisfactory.

Tuft Method

First an attempt was made to measure the strength of attachment of fibers to the seed by measuring the force necessary to detach a tuft of fibers by means of a pendulum-type machine for testing single strands of yarn. There are factors that pointed to the desirability of this method. It resembles the ginning process, where tufts of fibers are detached by the teeth of revolving saws. Testing by this method is also considerably more rapid and less laborious than the tedious task of testing single fibers. The chief objection to it is the inability to grip the tuft in the jaws of the machine, so that every fiber will be equally taut and thus support its equal share of the testing load. Care on the part of the operator in preparing the tuft and placing it in the jaws of the machine, can reduce this cause of error, however, and increase the accuracy of the work.

A tuft of 500 to 1,000 fibers was prepared by dividing the fibers upon the seed into approximately two equal groups and trimming one group by means of fingers and forceps to the desired size on the part of the seed to be tested. After straightening the fibers and removing the loose ones by careful combing, the ends of the fibers were cut off with scissors so that the tuft was slightly longer than 1/2 inch in length. The fibers on the opposite side of the seed were gripped in the upper jaws of the testing machine, and the prepared tuft was gripped close to the seed in the lower jaw. It is very important that the tuft be so gripped in order that there will be no shearing action but a sharp break when the breaking load is applied.

Figures representing the strengths of attachment were calculated by dividing the force (in grams) required to detach the tuft by the approximate number of fibers in the tuft. This approximation was made by dividing the weight of the detached tuft cut to exactly 1/2 inch, by the weight of 200 fibers selected from the tuft.

The figures thus obtained were considerably smaller than the figures representing the mean strength of fiber attachment obtained by testing individual fibers. This was to be expected since the composite strength of attachment of a tuft of fibers is influenced by the range and frequency distribution of the strength of attachment of the individual fibers, and thus is not equivalent to the product of the number of fibers multiplied by the mean strength of attachment. The method has, however, some possibilities for making rough comparisons or approximations. For instance, it was determined by this method, and later substantiated by more elaborate methods, that fibers on the rounded end of the seed are less strongly attached than fibers on other parts of the seed, whereas fibers on the pointed end are

most strongly attached; that fibers are less strongly attached to green (damp) seeds than to dry seeds; that the strength of fiber attachment varies between seeds of the same cotton, and that the average of one cotton may vary considerably from the average of another cotton (table 1).

Single-Fiber Method

The results obtained by the tuft method were not thought to be sufficiently accurate for fundamental studies of strength of fiber attachment to the seed. A single-fiber testing apparatus combining ease of operation and speed without sacrificing accuracy appeared to be more desirable, so a very simple instrument (fig. 2) meeting these requirements was constructed. It was modeled very closely after the pendulum-type, single-strand yarn testing machine and embodies no new principles except with respect to the manner in which the loading force is applied. The fiber is merely grasped by means of forceps, and the loading force is applied directly by hand. This makes the operation very simple and rapid.

This instrument consists of an aluminum pendulum (p) attached to a small aluminum wheel (w) pivoted at its center by means of a hardened steel axle pointed at each end and mounted between two jeweled bearings (j). The upright (u) supporting the wheel and pendulum is mounted upon an iron base (b) that can be leveled (s). A cotton seed with fibers attached (cs) is suspended by means of a hook (h) from a thread (t) that passes in a groove on the rim of the wheel to the opposite side of the wheel, where small weights (w) sufficient to exactly counterbalance the weight of the seed and hook are added. The thread is prevented from slipping by passing it through an eye with setscrew (i) for clamping the thread, located at the top of the wheel 180° from the pendulum. A force acting upon a fiber attached to the seed swings the pendulum along a graduated quadrant (q). Sufficient weight (m) has been added to the pendulum so that the force required to lift the pendulum through 90° is approximately equal to the force that will be necessary to detach the most strongly attached fibers from the seed (about 5.5 grams).

The scale was graduated empirically, by first adjusting the weights suspended from the thread until the pendulum reached a vertical position. The position was marked zero. By adding weights of known denominations to the hoop suspended from the right side of the wheel and marking the resulting positions of the pendulum on the quadrant, the scale was graduated. The midpoints of the divisions shown are 1/4 gram apart and are numbered from 1 to 22. that is, 1/4 gram to 22/4 grams respectively.

The fibers on the seed to be tested are divided into two approximately equal groups, the dividing lines running from end to end of the seed. One group serves as a means of suspending the seed from the hook, and if given a slight twist it will easily support the seed during testing. From the group on the opposite side small tufts are prepared for testing. Tufts of about 400 to 500 fibers are separated from the rest of the fibers at the position to be tested, - tip, middle, or base. The tuft is then trimmed to a thin row of about 275 to 300 fibers, following the length of the seed,

Table 1. - Strength of attachment of fibers 1/ at different positions on the seed as obtained by the tuft method for seven different cottons

Cotton designation	No. of seeds tested	Strength of fiber attachment				Average 2/ for cotton
		Chalazal end	Middle	Micropylar end		
		Grams	Grams	Grams		
A	120	0.132	0.200	0.268	0.200	
B	130	.173	.251	.356	.260	
C	10	.125	.156	.207	.163	
D	10	.154	.220	.280	.218	
E	10	.084	.126	.228	.146	
F	10	.148	.234	.310	.231	
G	10	.126	.179	.398	.234	

1/ Measurements of strengths of attachment were made for the seven cottons by the tuft method herein described.

2/ These averages do not take into consideration the variation in the number of fibers in the three different regions tested.

by detaching the fibers on both sides of the row with fingers and forceps. This can be done without disturbing the row of fibers to be tested if the operator works from the sides of the tuft and close to the seed. To facilitate testing and to avoid bias in sampling due to differences in length of fibers, the end of the tuft should be cut off $\frac{3}{4}$ inch to $\frac{1}{2}$ inch from the seed. The seed is then mounted on the hook in such a way that when a fiber is grasped and force applied, the fiber is at right angles to the surface of the seed.

With forceps (such as cover-glass forceps with broad sharp ends) the operator grasps a single fiber and with a combined movement of fingers, wrist, and elbow, force is applied as evenly and uniformly as possible for each fiber tested. The force required to detach the fiber is measured by the highest point reached by the pendulum along the graduated scale. This reading can be ascertained most accurately by a recorder sitting directly in front of the instrument.

Although the maximum point reached by the pendulum along the scale cannot be determined in every instance with exact certainty by the recorder, the operator can so regulate the rate of speed that there is no possible doubt in a very high percentage of the cases. The small number of cases that are in doubt will not affect the results to any great extent, since the data are grouped in class intervals of $\frac{1}{4}$ gram. It would be more desirable to have an automatic recording device, but the preliminary nature of these tests did not seem to warrant the additional expense that would be involved.

Preliminary tests were made with the newly developed instrument: (1) To ascertain its accuracy and (2) to establish sample size and sampling methods. The materials for these tests were obtained from seed cottons received at the U. S. Cotton Ginning Laboratory, at Stoneville, Miss. Growers in several States cooperated by furnishing this cotton for use in cotton-ginning tests, 8/.

The rate at which and the evenness with which the loading force is applied to a fiber are important factors affecting the force needed to detach that fiber from the seed. In making measurements with the new instrument, therefore, it should be borne in mind that some part of the difference between any two measurements is likely caused by the personal element. Measurements made with this new instrument compare favorably, however, with those made with a McKenzie apparatus for testing the tensile strength of single fibers (fig. 3), an instrument whose measurements are much less subject to the personal element. The latter instrument is similar to the one used by Dewey and Goodloe (see footnote 3).

Two comparative tests were made. First, the percentage of fibers in specified class designations of strength of attachment was obtained for 1,000 fibers (100 from the middle of each of 10 seeds), the test being made with the new instrument; 750 fibers (50 or 100 from the middle of each of 9 seeds taken from the same cotton) using the McKenzie tester. The 19 seeds used were taken from the middle of a lock from 19 different bolls

8/ Bennett, Charles A., and Gerdes, Francis L. Effect of Gin-Saw Speed and Seed-Roll Density on Quality of Cotton Lint and Operation of Gin Stands, U. S. Dept. Agr. Tech. Bul. 503, 1936, illus.

representing a certain seed cotton.

The frequency distributions obtained with the two instruments are similar, and the mean strengths of fiber attachment are only very slightly different, namely 1.156 grams for the McKenzie and 1.083 for the new instrument (table 2). Later studies have shown that, for the difference between the means of two cottons obtained from large samples to be significant, the measures must differ considerably more than do these.

To eliminate differences due to sampling, so far as possible, a second test was made. From each of five bolls of Stoneville #5 cotton one lock was taken. Two seeds from the middle of each of these locks were chosen for testing -- one on the McKenzie and the other on the new instrument. Two hundred and fifty-six fibers from the middle of each seed were tested.

There is a close similarity in the data obtained by the two instruments (table 3). Differences can be explained by possible differences between the two seeds and by experimental error. The mean strength of attachment of 1,280 fibers tested on the McKenzie tester was 1.321 grams, and the mean for the same number of fibers tested on the new instrument was 1.335 grams. A statistical analysis of these data (table 3) indicates that the difference between these means is not significant -- an F value of 6.68 being obtained, whereas an F value of 224.57 at odds of 19 to 1, or 5,625.14 at odds of 99 to 1, is necessary for significance.

Data obtained by means of the tuft and single fiber methods described above have indicated quite definitely that fibers at different positions on the same seed have different strengths of attachment. From tests made on 12 seeds taken from 4 different cottons, it may be concluded that fibers on the rounded end of the seed are less strongly attached than are fibers elsewhere on the seed, and that fibers on the pointed end are most strongly attached (table 4).

Thus, in ascertaining the mean strength of attachment of all fibers to a seed, differences due to location of the fiber must be taken into consideration; also, the relative number of fibers in each position must be considered. The area designated as the middle of the seed possesses more fibers than do either of the ends. Moreover, the fibers from this region have intermediate values of strength of attachment. Therefore, when comparing different seeds, it seems that a tuft of fibers upon the side of a seed and approximately midway between the two ends may be taken as representative.

Preliminary tests revealed that the smallest sample that could be used to represent at least fairly accurately the strength of attachment of fibers to any particular area upon a seed must contain at least 250 fibers. The standard error of the mean for samples from any particular area of the seed vary less sharply for samples increasingly larger than

Table 2. -- Strength of fiber attachment to seeds from the same cotton
as obtained by the McKenzie tester and by the new single-fiber tester

Strength of attachment	Frequency distribution					
	McKenzie tester			New tester		
	Grams	Total number	Percent	Total number	Percent	
0.25	: 19	:	2.5	: 79	:	7.9
0.50	: 153	:	20.4	: 114	:	11.4
0.75	: 108	:	14.4	: 257	:	25.7
1.00	: 157	:	20.9	: 155	:	15.5
1.25	: 69	:	9.2	: 134	:	13.4
1.50	: 96	:	12.8	: 94	:	9.4
1.75	: 53	:	7.1	: 62	:	6.2
2.00	: 44	:	5.9	: 44	:	4.4
2.25	: 18	:	2.4	: 29	:	2.9
2.50	: 11	:	1.5	: 14	:	1.4
2.75	: 7	:	.9	: 9	:	.9
3.00	: 8	:	1.1	: 4	:	.4
3.25	: 2	:	.3	: 5	:	.5
3.50	: 2	:	.3			
3.75	: 1	:	.1			
4.00	: 1	:	.1			
4.25	: 1	:	.1			
		:	:			
Total	: 750	1/	100.0	: 1,000	2/	100.0
Mean	:	1.156		:	1.083	

1/ 50 or 100 fibers from the middle of each of 9 seeds.

2/ 100 fibers from the middle of each of 10 seeds.

Table 3. -- Strength of attachment of fibers from 5 pairs of seeds, one pair from each of 5 locks, one seed of each pair being tested with the McKenzie single-fiber tester and the other with the new tester, with analysis of variance

Table 4. -- Strength of attachment of fibers at different positions on the seed, as obtained with new single-fiber tester

Cotton number	: Seeds tested	: Fibers tested	: Position on seeds from which fibers were taken	: Mean strength of attachment
	: Number	: Number		: Grams
315	:	1256	Rounded end	0.692
	3	1256	Middle	1.053
	:	856	Pointed end	1.470
319	:	:	:	:
	:	768	Rounded end	.895
	3	768	Middle	.982
	:	768	Pointed end	1.350
324	:	:	:	:
	:	768	Rounded end	.682
	3	768	Middle	1.040
	:	768	Pointed end	1.218
318	:	:	:	:
	:	768	Rounded end	.912
	3	768	Middle	1.245
	:	768	Pointed end	1.545

250 fibers, than for smaller samples (table 5). A sample of 256 fibers was chosen, instead of 250, for convenience in calculations.

Owing to the variation in mean strength of attachment of fibers for different seeds in the same seed cotton, at least 10, and preferably 16, seeds or more should be tested from each cotton. The sampling procedure adopted was to take 1 seed from the middle of each of 10 or more locks, each lock representing a different boll selected from the field. If picked seed cotton was to be tested, one seed was selected from the middle of each of 10 or more locks selected from a large sample.

TESTING OF INDIVIDUAL COTTONS

Forty-one different seed cottons were employed in tests made to compare the mean strength of fiber attachment of different cottons. Nine of the 41 lots of seed cottons were obtained from the U. S. Cotton Ginning Laboratory. These 9 cottons represent 9 different commercial strains, 6 of which were approximately 1-1/8 inches in staple, and the other 3 were approximately 1 inch in staple.

The other 32 seed cottons tested were from the 1935 and 1936 crop of the 16 foundation varieties used in the Regional Variety Test of the Bureau of Plant Industry grown at Stoneville, Miss. Bolls representing each cotton were selected from the field.

Nine cottons were first tested to ascertain whether different cottons of approximately the same staple length and character vary in the tenacity with which their fibers adhere to the seed. As stated previously, 6 of these cottons were about 1-1/8 inches in staple, and 3 were about 1 inch. They were all judged as normal with respect to character. The staple lengths and character designations were obtained from a U. S. Government classer's appraisal of lint ginned from the same lot of seed cotton from which the seeds were taken. The strength of attachment of the fibers to the seed was determined by testing individually 256 fibers from each of 10 seeds for each cotton, using the new tester. The technique and sampling methods have already been described.

The mean strength of attachment of fibers to the seed for seed cottons of approximately 1-1/8 inch staple was found to range from 1.033 grams for Deltapine to 1.617 grams for Stoneville 2B (table 6). Based on the lower figure this represents a difference of 50 percent plus. In light of the low value for the standard error of the mean, this difference is very significant. Cottons 431 and 425 are significantly different from cottons 419 and 434 at odds of 99 to 1 or greater. 9/ The differences found among the 3 short staple cottons tested namely cottons 426, 438 and 420, are not statistically significant at odds of 99 to 1 or 19 to 1. 9/

9/ Using Fisher's formula for comparing means:

$$t = \frac{M_1 - M_2}{\sqrt{(\bar{m}_1)^2 + (\bar{m}_2)^2}}$$

Table 5. The mean strength of fiber attachment, standard deviation and standard error of mean for samples of different size from different positions on the seed, as obtained by the new single-fiber tester

Seed number	Sample		Mean		Standard
	Position	Size	strength	Standard	error
	on seed		of attachment	deviation	of mean
		<u>Number</u>	<u>Grams</u>	<u>Grams</u>	<u>Grams</u>
1	Rounded end	100	0.598	0.338	0.034
		200	.631	.298	.021
		300	.657	.312	.018
		400	.661	.348	.017
		500	.656	.345	.015
	Middle	100	1.000	.472	.047
		200	1.094	.510	.036
		300	1.095	.505	.029
		400	1.124	.512	.026
		500	1.120	.510	.023
2	Pointed end	100	1.605	.602	.060
		200	1.502	.608	.043
		250	1.436	.602	.038
		100	.605	.308	.031
		200	.594	.330	.023
	Rounded end	300	.598	.310	.018
		400	.562	.292	.015
		500	.588	.292	.013
		100	.848	.385	.038
		200	.895	.408	.029
	Middle	300	.869	.392	.023
		400	.849	.390	.020
		500	.852	.402	.018
	Pointed end	100	1.332	.460	.046
		200	1.496	.538	.038
		300	1.510	.538	.031
		350	1.491	.540	.029

Table 6. - Mean strength of attachment of fibers to the seed, standard deviation, and standard error of the mean for nine varieties, as obtained with the new single-fiber tester

Cotton no.	Variety	Staple length <u>1/</u>	Character	Strength of attachment of fibers to seed <u>2/</u>		
				Standard error of mean	Standard	
					Mean	
		Inches		Grams	Grams	Grams
Medium staple group						
419	Deltapine	1-1/8	Normal	1.033	0.219	0.069
434	Farm Relief	1-1/16	"	1.067	.140	.044
429	Delpress	1-5/32	"	1.170	.190	.060
437	Stoneville #3	1-1/8	"	1.326	.436	.138
431	Stoneville 2A	1-1/8	"	1.350	.256	.081
425	Stoneville 2B	1-1/8	"	1.617	.144	.046
Short staple group						
426	D x P. L. #10	31/32	"	1.238	.340	.108
438	Dixie Triumph	31/32	"	1.348	.297	.094
420	Arkansas Rowden #40	1	"	1.433	.281	.089

1/ U. S. Government classer's staple length and character for ginned lint from same lot of seed cotton.

2/ Based on the mean strength of attachment of 256 fibers from each of 10 seeds for each seed cotton.

Using the same technique for testing and sampling, the strength of fiber attachment was measured next for the 1935 and 1936 crops of the 16 varieties of the Regional Variety test grown at Stoneville, Miss.

For the 1935 crop, either 10 or 16 seeds were tested for each cotton, depending upon the irregularity of the cotton. If, when 10 seeds were tested for 1 cotton the standard error of the mean was greater than 7 percent of the mean, 6 additional seeds were tested, bringing the total number of seeds tested to 16. For the 1936 crop, 16 seeds were tested for each variety.

Although some variation in the strength of fiber attachment to the different seeds of the same cotton was found, there were distinct differences in the means for each variety (tables 7 and 8).

The data were first reduced by analysis of variance. For both years the large "F" values show that the variance attributable to differences between cottons is highly significant (table 9).

Individual comparisons of each variety with every other one (see footnote 9) bring out more definitely those particular varieties which differ significantly in the strength with which fibers are attached to the seed. Significant (odds 19 to 1) and very significant (odds 99 to 1) differences between variety means are shown by the crosshatched and lined squares in figures 4 and 5. Each crosshatched and lined square indicates that the difference between the means of the two varieties being compared is significant while each lined square indicates that the difference is very significant.

Deltapine had the lowest strength of fiber attachment in both 1935 and 1936. In 1935 it differed significantly from 14 of the other cottons and very significantly from 11, while in 1936 it differed significantly from 6 and very significantly from 5. In 1935 Arkansas 17 possessed the greatest strength of fiber attachment and differed significantly from 10 of the other cottons and very significantly from 9. In 1935 Startex had the greatest strength of fiber attachment and differed very significantly from all of the other 15 cottons.

When the results of 1935 and 1936 are compared, some differences are found. Eight varieties measured stronger in 1935 than in 1936, and eight weaker. No variety, however, varied an amount sufficiently large to be considered statistically significant. The t value for the differences between the 2 years was found to be 0.0207, whereas a value of 2.947 (odds 99 to 1) is needed for significance, indicating that differences between the results for the 2 years may be largely the result of errors of sampling and perhaps also errors of measurement rather than actual differences in strength of attachment of fibers.

A more complete comparison of the strength of fiber attachment of different cottons can be obtained by comparing their frequency distributions. The usual range of variation in the strength with which individual fibers

Table 7.—Mean strength of fiber attachment as obtained with the new single fiber tester for the tested seeds of 16 varieties grown at Stoneville, Miss., in 1935, with the mean, standard deviation, and standard error of the means for each variety

Seed no.	Mean strength of fiber attachment 1/															
	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams
1	:1.132:1.108:1.164:1.422:1.490:1.192:1.146:1.845:1.296:1.365:1.073:1.121:0.888:1.258:1.404:1.589	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
2	:0.902:1.120:0.967:1.310:1.116:1.380:1.276:1.007:1.174:1.214:1.301:1.336:1.436:1.110:1.348:1.565	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
3	:1.094:1.083:1.202:1.047:1.142:1.319:1.222:1.126:1.212:1.917:0.786:1.310:1.924:1.644:1.350:1.602	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
4	:1.016:1.388:1.141:1.378:1.173:1.337:1.055:1.218:1.098:1.671:1.205:1.098:1.613:1.491:1.582:1.278	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
5	:1.146:0.900:0.806:0.958:1.112:1.328:1.281:1.492:1.450:0.668:1.651:1.134:1.377:1.984:1.501:1.521	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
6	:0.708:0.892:1.176:1.350:1.052:1.224:1.180:1.207:1.545:1.197:1.423:1.800:1.215:1.651:1.370	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
7	:1.006:0.810:1.202:1.347:1.347:1.400:1.023:1.583:1.195:1.287:1.367:1.566:1.386:1.192:1.164:2.073:1.770	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
8	:1.006:1.277:1.184:0.902:1.381:1.341:1.129:1.367:1.703:0.969:1.476:1.502:1.354:1.894:1.323:1.734	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
9	:0.916:0.980:1.208:1.118:1.221:1.233:1.204:1.238:1.280:1.318:1.419:1.372:1.509:1.213:1.398:1.436	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
10	:1.336:1.206:1.188:1.198:0.938:1.159:1.310:1.325:1.206:1.285:1.330:1.330:1.888:1.828:1.426:1.466:1.488	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
11	:1.1:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428:1.428	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
12	:1.1:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335:1.335	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
13	:1.1:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417:1.417	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
14	:1.1:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166:1.166	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
15	:1.1:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262:1.262	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
16	:1.1:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288:1.288	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
<hr/>																
Mean 2/																
σ	:0.169:0.183:0.152:0.187:0.170:0.127:0.142:0.225:0.170:0.298:0.258:0.355:0.267:0.355:0.223:0.152	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
σ_m	:0.053:0.058:0.038:0.059:0.054:0.040:0.045:0.056:0.054:0.074:0.071:0.065:0.067:0.067:0.089:0.056:0.048	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

1/ Mean for each seed based on 256 fibers.

2/ Values for each cotton based on means of 10 or 16 seeds.

Table 8.—Mean strength of fiber attachment as obtained with the new single fiber tester for each of 16 varieties grown at Stoneville, Miss., in 1936, with mean, standard deviation, and standard error of the mean for each variety

Mean strength of fiber attachment 1/ 2/																
Seed no.	Deltapine	CleveLand	(West)	W11d	Q11d	Deltros	#912	#4	Big Hal							
1	1.255:1.230:1.111:1.170:1.206:0.929:1.131:1.305:0.821:1.074:1.367:1.318:1.352:1.316:0.965:2.245															
2	0.585:1.640:1.104:1.088:1.177:1.130:1.486:1.564:1.080:0.971:1.150:1.354:1.588:2.171:1.375:1.825															
3	1.014:0.980:1.434:1.071:0.971:1.410:1.379:1.459:1.308:1.181:1.383:1.373:1.520:1.308:1.802:1.132															
4	1.494:0.987:0.946:1.088:1.198:1.136:1.257:1.280:1.379:1.883:1.248:1.366:1.218:1.588:1.131:2.230															
5	0.966:1.375:1.054:1.493:1.086:1.133:1.224:1.289:1.026:1.598:1.166:1.027:1.179:1.551:1.569:1.613															
6	0.791:1.182:0.945:1.142:1.146:1.324:1.100:1.226:1.334:1.522:1.201:1.296:1.696:1.679:1.207:1.792															
7	1.125:1.053:0.976:0.751:1.239:0.978:1.084:1.420:1.342:1.342:1.169:0.819:1.257:1.199:1.062:1.473:2.032															
8	0.818:0.955:1.264:1.407:1.448:1.316:0.976:1.131:1.014:1.018:1.376:0.968:1.122:1.087:2.052:1.732															
9	0.966:1.003:1.232:1.168:1.339:1.356:1.462:1.750:1.087:1.304:1.900:1.635:1.932:1.263:1.347:1.581															
10	1.221:1.184:0.860:1.094:1.444:1.400:1.517:0.876:1.072:0.924:1.522:1.578:1.423:1.104:1.274:1.646															
11	1.088:1.184:1.070:1.104:0.925:1.480:1.129:1.072:1.350:1.193:1.776:1.148:1.323:1.954:1.420:1.400															
12	1.004:1.083:1.381:1.200:1.277:0.805:1.510:1.240:1.176:1.298:1.431:1.524:1.562:1.348:1.598:1.808															
13	1.387:0.930:1.204:1.136:1.224:0.829:1.390:1.044:1.744:1.377:1.172:1.258:0.768:1.487:1.432:1.703															
14	1.049:1.093:1.006:1.150:0.905:1.246:1.415:1.080:1.373:1.429:1.239:1.434:1.049:1.175:1.587:1.622															
15	1.701:1.154:1.026:1.358:0.892:1.594:1.232:1.132:1.380:1.258:1.281:1.653:1.495:1.415:1.465:1.823															
16	0.980:0.969:1.587:1.022:1.225:1.363:0.575:1.197:1.916:1.243:1.403:1.923:1.468:1.316:1.585															
Mean 2/ 1.107:1.125:1.138:1.153:1.169:1.202:1.229:1.254:1.275:1.340:1.382:1.397:1.436:1.433:1.736																
σ^2 0.250:0.183:0.200:0.168:0.175:0.218:0.237:0.216:0.275:0.248:0.253:0.243:0.313:0.307:0.258:0.280																
σ_m 0.063:0.046:0.050:0.042:0.044:0.054:0.059:0.054:0.054:0.069:0.063:0.062:0.069:0.061:0.063:0.065:0.070																

1/ Mean for each seed based on 256 fibers.

2/ Mean for each cotton based on means of 16 seeds.

Table 9.—Analysis of variance of strength of fiber attachment to the seed as obtained with the new single-fiber tester for 16 varieties grown in 1935 and 1936 at Stoneville, Miss.

Source of variation		Degrees of freedom	Sum of squares	Mean square	F found	F required at 5 pct.: 1 pct.
1935						
Disproportionate samples 10 or 16	Total	207	14.206057			
seeds for each cotton	Between means of cottons	15	3.941757	0.262784	4.92	1.74 : 2.17
cotton	Within cottons	192	10.264270	.053450		
1936	Total	255	20.466410			
	Between means of cottons	15	6.314062	.420937	7.14	1.74 : 2.17
	Within cottons	240	14.152348	.058968		

are attached to any particular area upon a seed is from 0.25 to about 5.00 grams, with the distribution skewed toward the stronger strengths. Table 10 gives the frequency distribution on a percentage basis for each of the 16 varieties grown in 1935. Although there are relatively small differences in the extreme ranges of different cottons, their frequency distributions within the range are different. These differences in distributions can be seen from a comparison of their means (M), standard deviations (σ), coefficients of variability (v), modes, and medians. ^{10/} The means have been used for making comparisons. However, the relationship of strength of fiber attachment to gin damage of individual fibers and to ginning efficiency may be more closely associated with the mode or median. These averages are not influenced by the magnitude of extreme variations.

The medians show about the same degree of variation as the means and follow about the same sequence as the means, but the modes have a much greater degree of variation than either. The median varies from 0.917 grams in Deltapine to 1.421 grams in Arkansas #17, whereas the mode varies from 0.567 grams in Deltapine to 1.469 grams in Arkansas #17.

SUMMARY

In order to ascertain whether the strength of fiber attachment to the cotton seed constitutes an important factor in efficient ginning, it was first necessary to develop or adopt an instrument to measure the force required to detach fibers from the seed.

Preliminary studies were made in which tufts of fibers were pulled from the seed by means of an apparatus for testing single strands of yarn and figures were calculated to represent the strength of fiber attachment to the seed for the cotton as a whole, for individual seeds, and for fibers at different positions on the seed. These figures were considerably smaller than figures representing the mean strength of fiber attachment obtained by testing individual fibers, and not considered to be sufficiently accurate for fundamental studies.

The use of the McKenzie apparatus for testing the tensile strength of single fibers was too time consuming for the studies contemplated.

Eventually a very simple instrument of the pendulum type and appropriate technique were developed for measuring the force required to detach single fibers from the seed. To eliminate the most tedious and time-consuming part of the operating required when using other instruments, namely, gripping the fiber in the jaws of a machine through which a loading force is applied, the fiber is merely grasped by means of a pair of forceps and the loading force is applied directly by hand.

Comparative tests show that a skillful operator can attain the same accuracy as with a McKenzie single-fiber tester.

^{10/} Values based upon individual fiber strength of attachment.

Table 10.—Frequency distribution strength of attachment of the individual fibers as obtained with the new single-fiber tester, on a percentage basis, for each of the 16 varieties grown at Stonerville in 1935, with mean, standard deviation, coefficient of variability, mode, and median for each variety

Strength of attachment in grams	Frequency distribution in percent for each of the 16 varieties															
	* #75	* #44	* #2	* #5	* #4	* #7	* #44	* #5	* #4	* #7	* #4	* #5	* #4	* #7	* #4	* #5
M.P.	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:	Pct.:
0.25	5.7:	5.5:	3.7:	3.4:	1.4:	2.9:	4.7:	2.8:	2.6:	3.9:	4.5:	1.6:	2.3:	2.9:	1.5:	1.0
0.50	22.1:	16.9:	15.4:	13.0:	12.8:	11.3:	11.9:	11.1:	9.7:	12.6:	8.4:	8.2:	7.2:	10.0:	5.7:	5.0
0.75	19.0:	18.2:	17.2:	14.6:	15.1:	16.0:	16.4:	16.2:	14.3:	14.0:	12.7:	11.7:	16.3:	12.8:	12.8:	9.3
1.00	18.9:	19.9:	16.9:	20.3:	20.7:	21.4:	20.1:	19.1:	19.0:	16.6:	16.7:	16.7:	15.8:	14.7:	15.4:	15.9
1.25	11.2:	13.5:	13.2:	14.7:	15.4:	14.5:	12.6:	15.3:	15.5:	13.3:	15.2:	14.4:	14.4:	12.0:	14.9:	15.7
1.50	10.0:	11.6:	11.9:	13.4:	13.8:	12.6:	11.2:	12.8:	14.1:	12.9:	12.4:	14.8:	11.4:	12.5:	13.6:	16.8
1.75	4.6:	5.7:	7.9:	7.3:	7.4:	7.1:	7.5:	7.3:	9.9:	7.5:	10.0:	8.8:	8.8:	8.9:	10.1:	10.4
2.00	3.5:	4.0:	5.7:	6.0:	5.7:	5.3:	5.5:	6.2:	6.1:	7.0:	6.5:	8.7:	6.9:	7.4:	8.8:	8.6
2.25	2.1:	1.8:	2.7:	2.7:	3.0:	2.5:	2.9:	2.7:	3.2:	3.9:	4.4:	4.4:	4.4:	4.7:	4.7:	4.9
2.50	1.1:	1.6:	2.2:	2.1:	2.1:	2.6:	2.2:	2.2:	3.5:	3.5:	3.5:	3.7:	3.7:	3.8:	4.5:	4.1
2.75	0.7:	0.7:	1.3:	1.3:	1.2:	1.3:	1.7:	1.7:	1.6:	1.8:	2.5:	2.5:	2.8:	3.3:	3.2:	2.8
3.00	0.5:	0.5:	0.9:	0.5:	0.4:	0.4:	0.9:	0.7:	1.1:	0.7:	1.3:	1.0:	1.0:	1.4:	1.7:	2.1:
3.25	0.2:	0.2:	0.5:	0.5:	0.3:	0.4:	0.8:	0.7:	0.6:	0.8:	0.8:	0.8:	1.2:	1.3:	1.8:	1.2
3.50	0.1:	0.0:	0.2:	0.2:	0.2:	0.3:	0.6:	0.4:	0.2:	0.4:	0.4:	0.5:	0.5:	0.7:	0.7:	0.7
3.75	0.1:	0.1:	0.2:	0.2:	0.2:	0.2:	0.7:	0.2:	0.2:	0.3:	0.4:	0.7:	0.7:	0.5:	0.6:	0.7
4.00	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.2:	0.3:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.5:	0.4
4.25	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.2:	0.1:	0.1:	0.3:	0.3:	0.2:
4.50	:	:	:	:	:	:	0.0:	0.2:	0.1:	:	0.0:	0.1:	0.1:	0.1:	0.1:	0.1:
4.75	:	:	:	:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.2:
5.00	:	:	:	:	:	0.0:	0.2:	0.1:	:	0.0:	0.1:	0.1:	0.1:	0.1:	0.1:	0.2:
5.25	:	:	:	:	:	0.1:	0.1:	0.1:	:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1:	0.1

1/ Values based upon individual fiber strengths of attachment, 2,560 fibers (or 4,096 fibers) from 10 (or 16) seeds.
* based upon 2,560 fiber measurements.
† based upon 4,096 fiber measurements.

The strength of attachment of fibers on any given area of any particular seed varies from about 0.25 grams to about 5.5 grams.

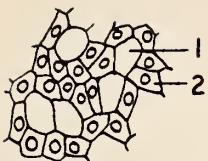
The mean strength of fiber attachment also varies from area to area on the seed. The fibers on the rounded (chalazal) end of the seed have the lowest strength of attachment, and those on the pointed end have the highest.

A sample of 256 fibers on the side of a seed approximately half-way between the ends was considered to be a representative sample for a seed. For comparing 2 cottons, at least 10 (preferably 16) seeds, one from each of 10 (or 16) bolls representing each cotton, are necessary. Each seed is taken from the middle of the lock selected to represent the boll.

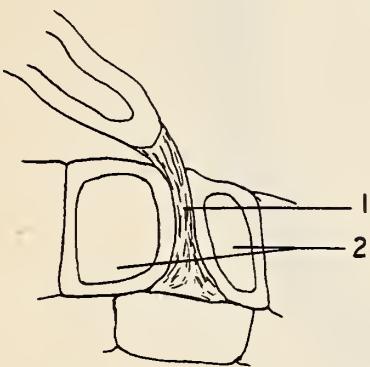
Comparative tests of 41 selected cottons of different varieties and covering a wide range of seed-cotton characteristics have shown that very significant differences exist between different varieties. Significant differences are apparent for cottons of the same staple length.



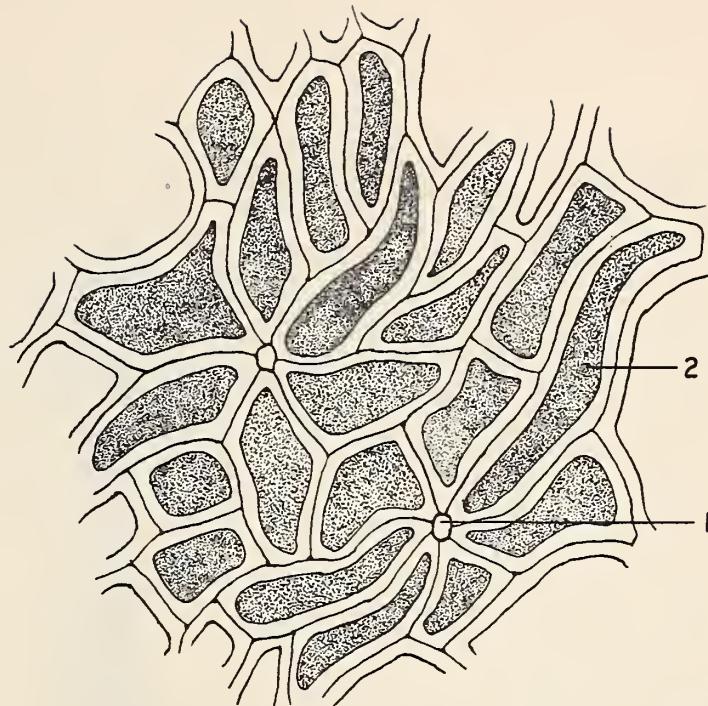
A



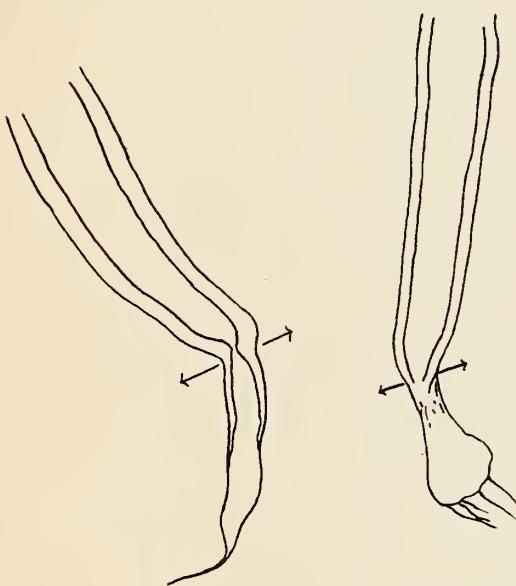
B



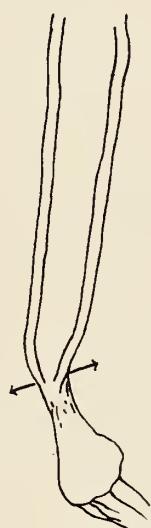
C



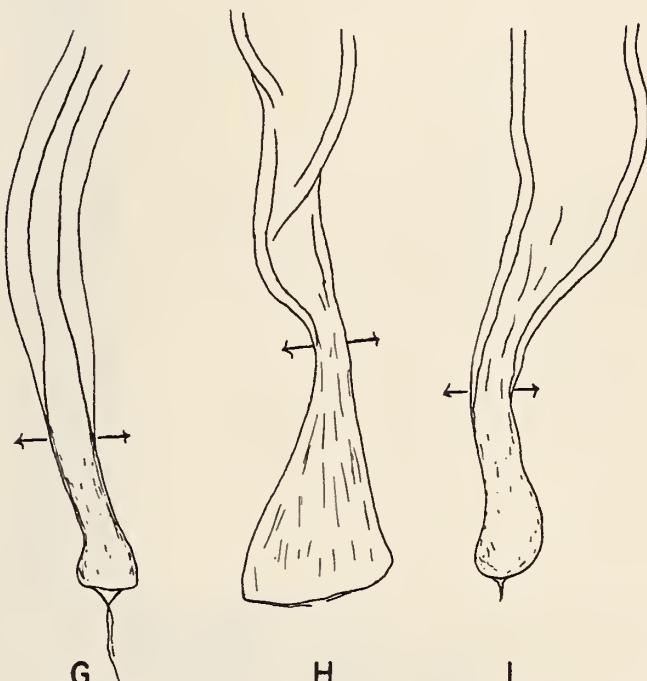
D



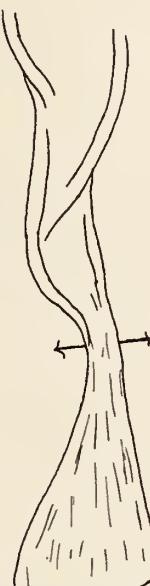
E



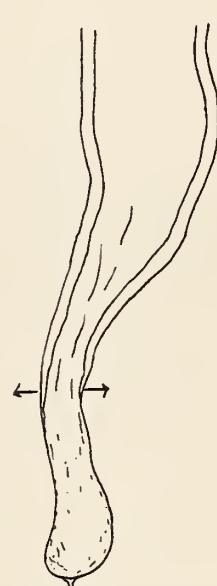
F



G



H



I

Figure 1.--A, Section through epidermis of a 5-day old seed showing the base of a cotton fiber (1) and the surrounding epidermal cells (2). B, Surface view of epidermis of a 5-day old seed showing fiber bases (1) and epidermal cells (2). C, Section through the epidermis of a 42-day old seed showing fiber base (1) and epidermal cells (2). D, Surface view of epidermis of 42-day old seed from which the fibers have been removed,--fiber scar (1), and epidermal cell (2). E, F, G, H, and I, Basal portion of fibers of 42-day old seeds that have been dissected from the epidermis,--arrows indicate the probable height of the epidermal cells. All figures X340.

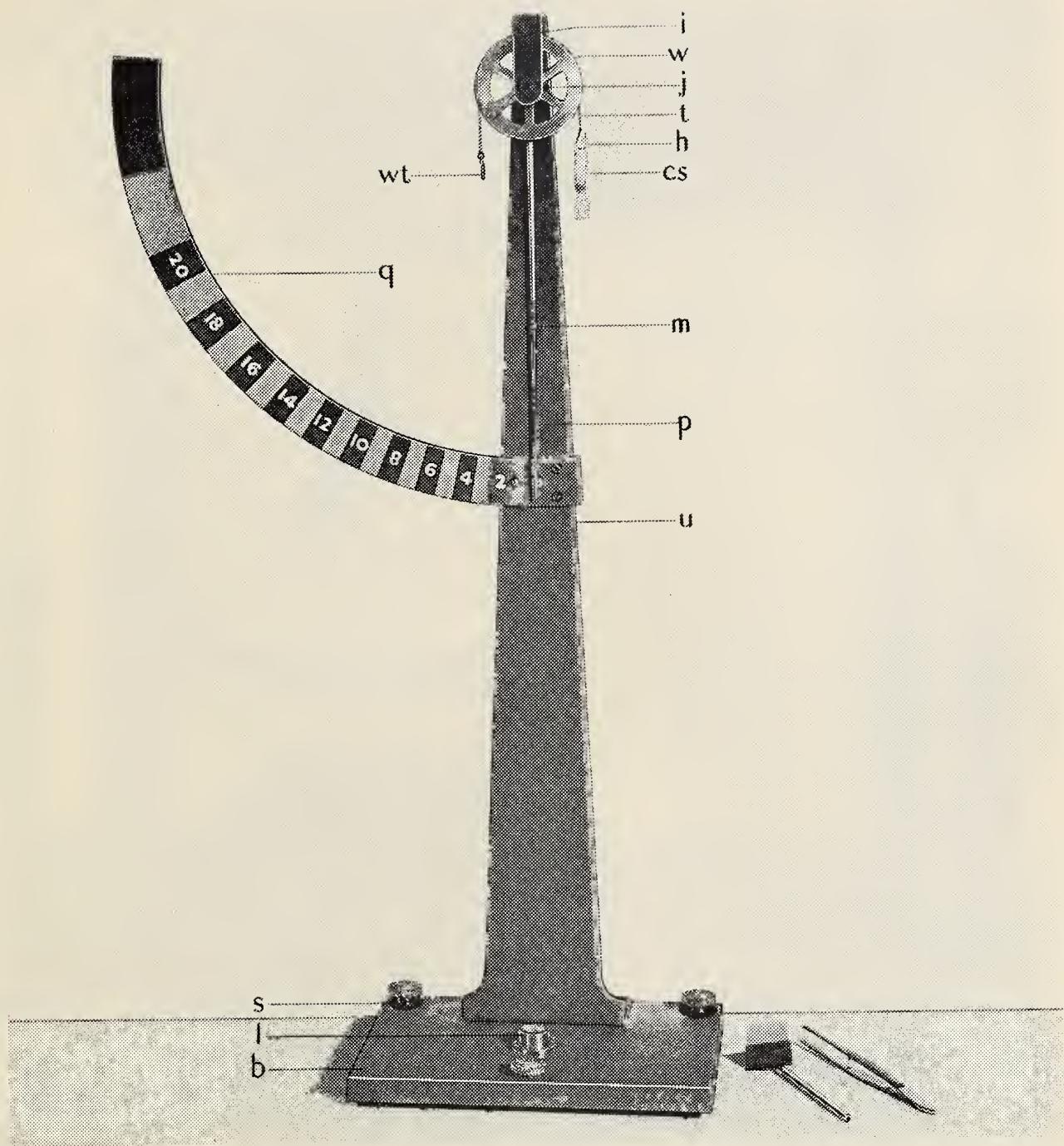


Figure 2.--The new single-fiber tester for measuring the strength of fiber attachment to the cotton seed; p, pendulum; w, aluminum wheel; j, jeweled bearings; u, upright support; b, base; l, level; s, leveling screws; cs, cotton seed; h, hook; i, set screw; t, thread; wt, weight; q, graduated quadrant; m, pendulum weight.

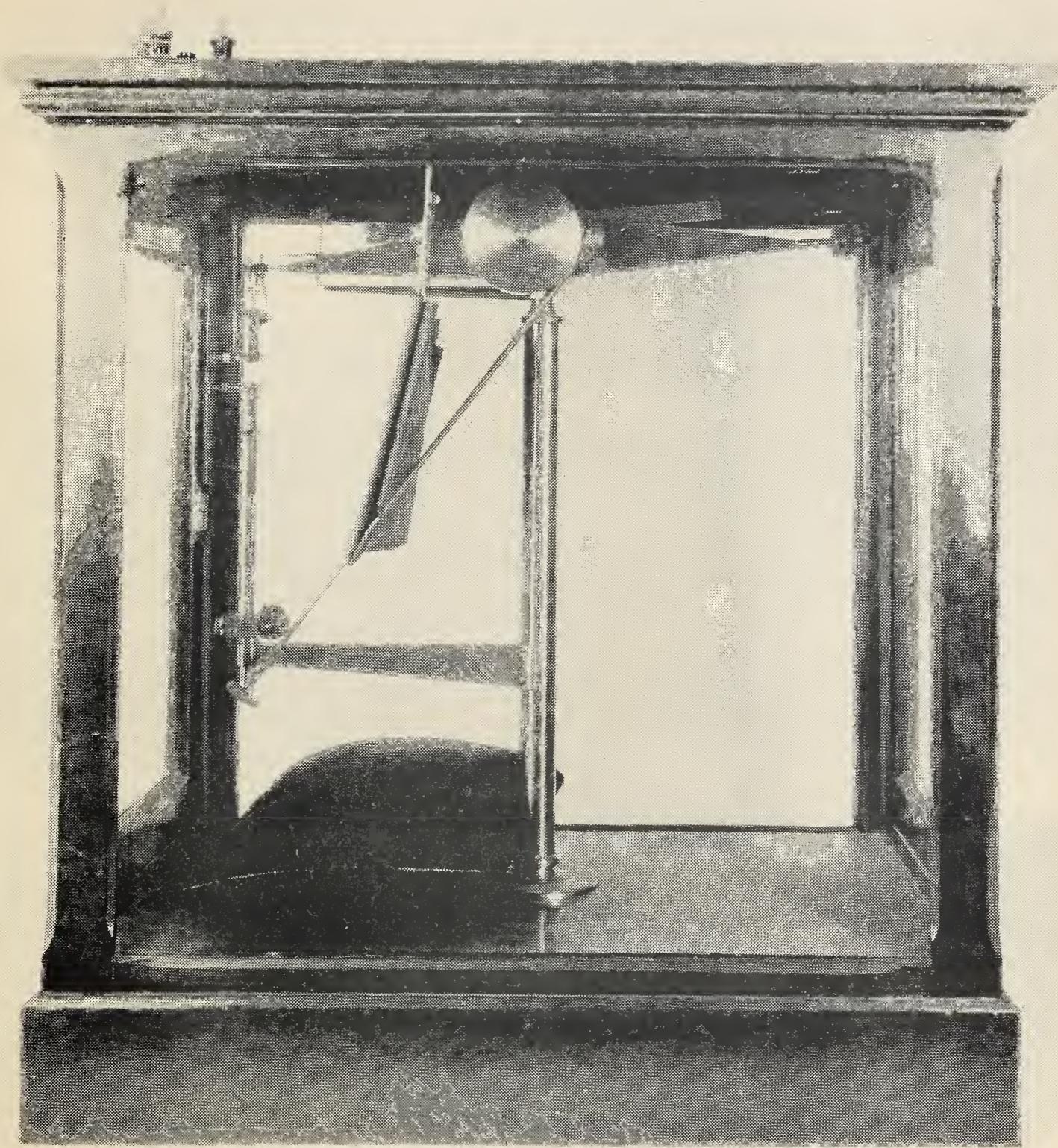
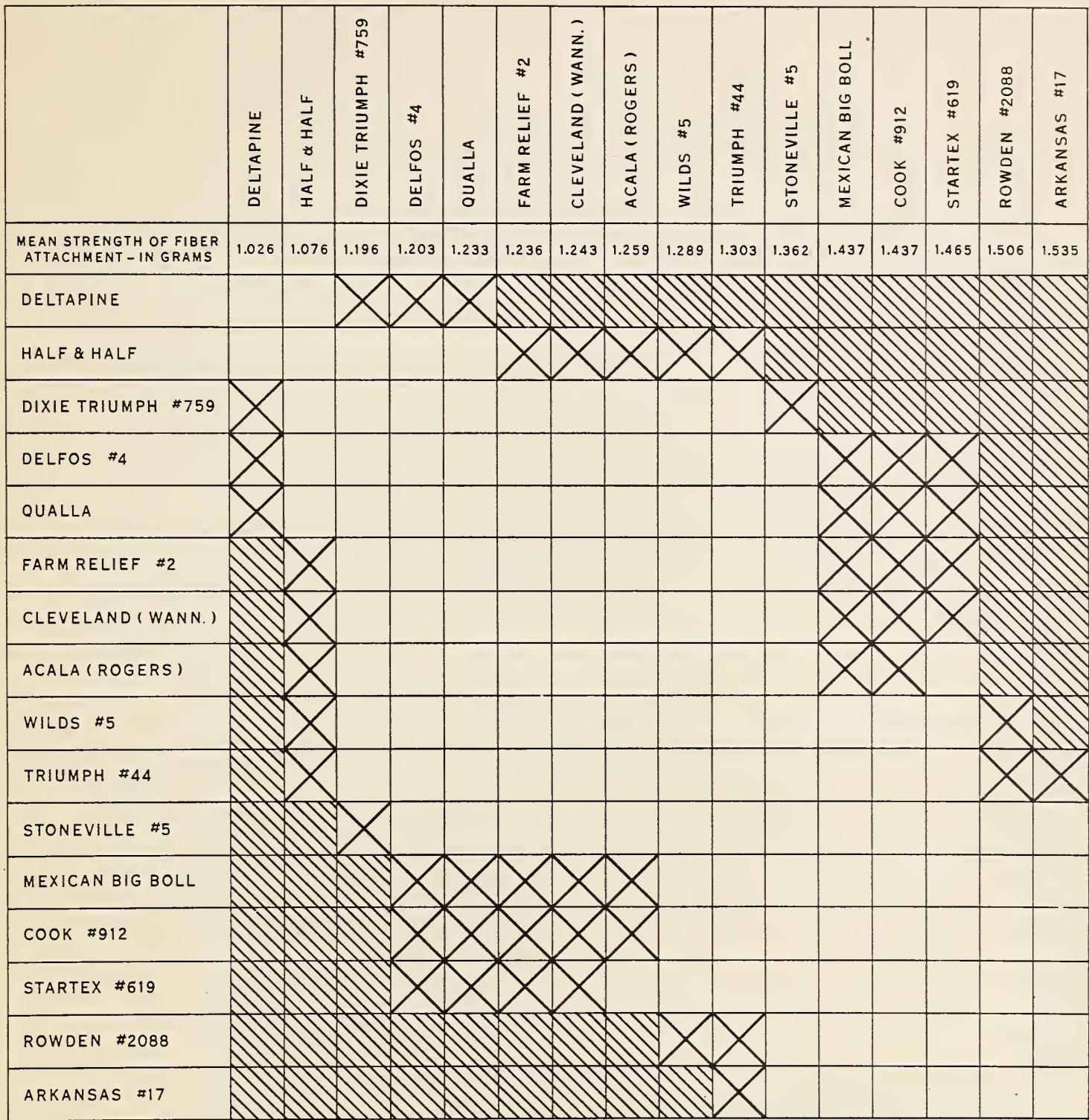


Figure 3.--The McKenzie single-fiber tensile strength testing apparatus.



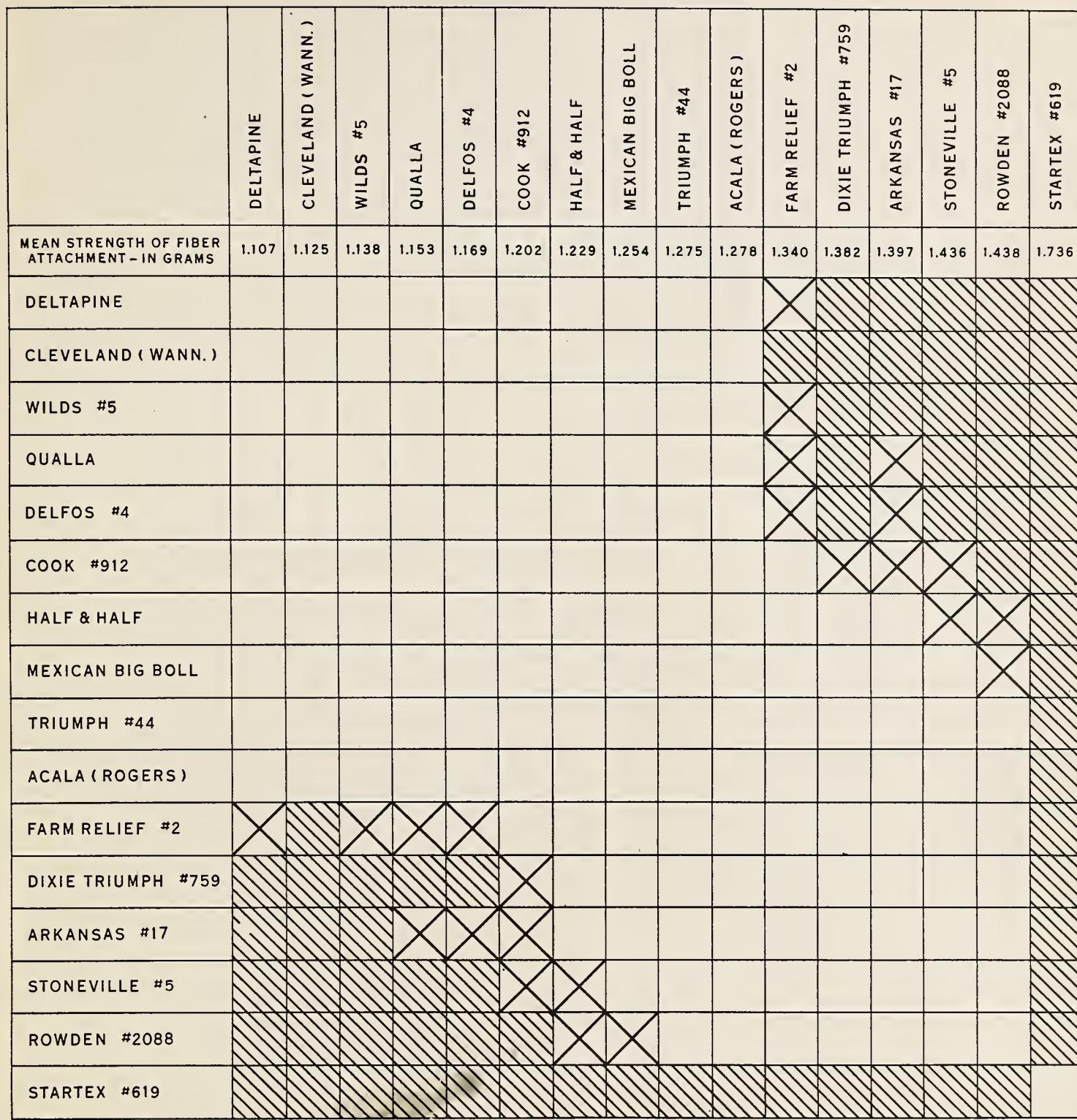
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Figure 4.--Varieties of cotton grown at Stoneville, Miss., in 1935
that are and are not significantly different in mean strength
of fiber attachment to the seed as determined by values of t .

$$t = \frac{M_1 - M_2}{\sqrt{(m_1)^2 + (m_2)^2}} ; \quad n = 32, 26 \text{ or } 20. \quad \text{All crosshatched}$$

and lined squares indicate varieties whose means differed significantly (odds 19 to 1). Lined squares indicate those varieties whose means differed very significantly (odds 99 to 1).



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Figure 5.--Varieties of cotton grown at Stoneville, Miss., in 1936 that are and are not significantly different in mean strength of fiber attachment to the seed as determined by values of t .

$$t = \frac{M_1 - M_2}{\sqrt{(O_m)_1^2 + (O_m)_2^2}} ; n = 32. \text{ All crosshatched and lined}$$

squares indicate varieties whose means differed significantly (odds 19 to 1). Lined squares indicate those varieties whose means differed very significantly (odds 99 to 1).

